*THE STRUCTURE OF THE FRUIT IN THE ORDER RANUNCULACEÆ.**

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KARL MCKAY WIEGAND, Ithaca, N. Y.

POSITION AND AFFINITIES.

The order *Ranunculaceæ* is an assemblage of species varying greatly from each other. The members are less closely related in general features than in most any other order, but they all agree in having separate floral parts and anatropous seeds. By most modern authors they have been taken as representing the typical floral structure, and I suppose for this reason they have been placed at the head of the *Polypetalae*. This position is not now considered logical since they obviously represent a comparatively primitive type, and following the arrangement of these authors should come last instead of first. For example, Dr. Gray's arrangement, very nearly like that of Bentham and Hooker, commences with the *Polypetalae* following which are the *Monopetalae*, *Apetalae*, *Gymnospermae*, and *Monocotyledones*. The order of progression is then from the more specialized to the more generalized.

Hence the *Ranunculaceae* should be near the end of the Polypetalae. As before stated, Engler and Prantl have based their system of classification more upon the fruit which seems to bring the orders into a much more natural relation with each other.

HISTORICAL.

In 1773, A. L. de Jussieu (1) read a paper before the Academie des Sciences on the *Ranunculi*. With this paper commenced

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Note.—Numbers after the names of authors refer to the Bibliography.

the history, not alone of the order *Ranunculaceae*, but of the whole natural system. The order is first recorded in de Jussieu's Gen. Plant. of 1789 as the order *Ranunculi*. De Candolle (2) changed the name to *Ranunculacae* in 1818. By some of the authors since that time, the order has been divided into two, the Pæonies being separated, but in late years they have again been united.

FRUIT IN GENERAL.

As before stated, one important character of the order as used in our present works on classification is based upon a general feature of the fruit. This is the fact that the carpels comprising the gynoecium are separate. Their number ranges from one to very many, the greatest number being found in some species of *Anemone*, *Ranunculus* and *Myosurus*. An exception to the rule occurs in *Nigella*, where the carpels are united almost to the top of the ovary. It is a general rule that the carpels are more numerous in the genera, bearing achenes, than in the pod forms; but in *Hepatica* and *Anemonella* the number is again small. The receptacle in most species is flat or slightly convex, but in *Ranunculus*, *Anemone* and *Myosurus* it becomes elongated to cylindrical and long cylindrical. In *Pæonia* it is concave.

Two kinds of fruit predominate in the order, the achene and the pod. By the term pod I refer to those fruits whose carpels dehisce at maturity for a greater or less distance down the ventral margin, thus allowing the seeds to escape. The term achene signifies those fruits of the order which are one seeded and at the same time indehiscent. Indehiscent fruits are profitable to the plant only when one seeded, since if several seeds were bound up together their chances of survival on germination would be very small. The achenes of the order *Ranunculaceae* are recent productions, since the line of dehiscence is still visible between the placental strands of most species.

The genera, producing achenes, are *Ranunculus*, *Adonis*, *Myosurus*, *Clematis*, *Anemone*, *Thalictrum*, *Oxygraphis*, *Trautvetteria*, and *Hamadryas*. Those producing pods are *Caltha*, *Trollius*, *Callianthemum*, *Helleborus*, *Eranthis*, *Nigella*, *Leptopyrum*, *Isopyrum*, *Coptis*, *Xanthorrhiza*, *Anemonopsis*, *Actæa*, *Aquilegia*, *Delphinium*, *Aconitum*, *Glaucidium*, and *Pæonia*.

The other form of fruit occurring in the order is the berry found in *Actæa* and *Hydrastis*. These will be considered at length in the subsequent discussion of the ovary, The pods all dehisce the whole length of the placenta ; hence, when this is only at the top of the pod they open only at this point.

The carpels are mostly short and are either broadly or narrowly elliptical and tipped with the persistent style which is variable in length. In *Ranunculus*, *Myosurus* and *Caltha* they are somewhat ventricose. The surface is either hairy, smooth, or warty, and will be described at length below.

I shall now discuss each part of the fruit separately, commencing with the seed.

THE SEED.

The Seed in General.

In the order *Ranunculaceæ*, the seeds conform to one distinct type throughout. They are completely anatropous in almost every species (except in *Hydrastis* and *Adonis*, where they are partly amphitropous). Perhaps there is no feature more constant in the whole order than this. No matter whether the seed be suspended or erect, this anatropous condition is still adhered to.

The general form and outline is somewhat peculiar and deserves notice. In the pod forms, the seeds may be classed under one type in this respect. They are obovoid with the smaller part at the hilum, and broadening toward the distal end. The exceptions are in *Coptis* and *Caltha* where they are elliptical, and in *Actæa* where they are semi-lunar. In the pod species the raphe is often very prominent, extending down one side in the form of a wing. The wing is especially prominent in species of *Aquilegia*, *Isopyrum*, and *Helleborus*, (Pl. I, 7, 8 ; 5, 6 ; Pl. III, 31, 32), while in *Pæonia*, *Delphinium*, *Coptis*, *Aconitum*, *Xanthorrhiza*, *Caltha* and *Hydrastis*, it is reduced to a mere ridge, (Pl. I, 1, 2 ; Pl. III, 33, 34 ; Pl. I, 9, 10 ; Pl. III, 35, 36 ; Pl. II, 11, 12 ; 25, 26 ; Pl. I, 3, 4). In *Actæa* (Pl. II, 21, 22) the surface over the raphe is depressed, leaving a distinct furrow where the wing is in other species. The seeds of *Isopyrum biternatum* are so like those of *Aquilegia Canadensis* in outline, that if one was not yellow and the other black they could scarcely be told apart.

In the achene forms the seed conforms very closely to the shape of the ovary in general outline, except in some cases of in flated fruits, as in *Ranunculus*. The raphe is generally present as a ridge, but is scarcely ever prominent enough to be called a wing in the species studied.

The form, which the seeds take on, seems to be well adapted to secure planting in the right position. The smooth surface and the tapering lower end would allow the seed to more easily slide down into the soil through the debris that might lie in its way, and the position would be such that the hypocotyl would be in close connection with the ground ready for germination. Special provisions in some species make this view seem more probable. In *Caltha* (Pl. II, 25, 26) a large air space is provided at the chalazal end of the seed. This space occurs also in some achene forms, as *Ranunculus Cymbalaria*. In these cases it is all the more important since the seeds are not tapering below. The heavy end would, of course, fall through the grass first.

The Embryo.

The type found in the order is remarkable as illustrating an extreme form of the albuminous embryo. In all species so far as observed they are very small, not over one-half the total length of the seed, and in many cases reduced to a stage not far removed from fertilization; and in which there is no differentiation of parts. In general, the smallest and least differentiated embryos are found among the pod forms.

Tho following is a brief outline of the principal features in the different genera studied:

Coptis, Minute, spherical, undifferentiated. (Pl. I, 9, 10.)

Hydrastis, Minute, spherical, undifferentiated. (Pl. I, 3, 4.)

Isopyrum, Minute, spherical, undifferentiated. (Pl. I, 5, 6.)

Helleborus, Small, nearly spherical, but truncate at top. (Pl. III, 31, 32.)

Caltha, Small, nearly spherical or short oblong, two small lobes at the top representing cotyledons. (Pl. II, 25, 26.)

Actæa, small, obovoid, but possessing two equal cotyledons one-half the length of the hypocotyl. (Pl. II, 21, 22.)

Xanthorrhiza, Medium, oblong, long hypocotyl, and cotyledons one-third as long. (Pl. II, 11, 12.)

Aconitum, Medium, cotyledons slightly longer than hypocotyl, well developed. Pl. III, 35, 36.)

Delphinium, Large, three-fourths length of seed. Cotyledons twice as long as the hypocotyl, unequal, broader than hypocotyl, well developed. Plumule present. (Pl. III, 33, 34.)

Pæonia, Large, one-fourth length of seed. Cotyledons equal to the hypocotyl in length, but broader. Pl. I, 1, 2.)

Hepatica, Minute, spherical, undifferentiated. (Pl. II, 17, 18.)

Ranunculus, Medium, obovoid; cotyledons one-half as long as hypocotyl, divergent. (Pl. III, 27, 28.)

Anemone, Larger, oblong; cotyledons one-half hypocotyl. (Pl. II, 15, 16.)

Thalictrum, Large, oblong; cotyledons two-thirds hypocotyl. (Pl. II, 13, 14.)

Clematis, Large, oblong; cotyledons two-thirds hypocotyl. (Pl. II, 19, 20.)

It will be seen from the above table that in all cases except two or three, the embryo is very small and either globular or short cylindrical in outline. In only one of the species studied did it exceed one third the length of the endosperm, and in by far the greater number it was minute. The one referred to is *Delphinium*. The size and high development of the embryo is remarkable for this order. Indications of a plumule were found in this species only.

In all the more highly developed embryos a well differentiated central cylinder occurs, and in some species branches from it are sent off into the cotyledons. These branches are visible in cross section as a single spot, but in *Delphinium* and *Paeonia* this is still farther divided into several branches forming a number of longitudinal nerves.

The general tendency in all orders seems to be for the more generalized forms to have shorter cotyledons in proportion to the length of the hypocotyl, but this cannot be stated as a rule since so many exceptions occur owing to the reduction of the ovary and other causes, especially among the albuminous forms. This will be seen to hold true to some extent in this order when a careful study of its ancient history is made. The exact size and form of the embryo may be seen from the outline drawings at the end of the paper.

The root cap can be distinguishid in the following genera : *Pæonia*, *Delphinium*, *Thalictrum*, *Aquilegia*, *Clematis*, *Anemone*, and *Ranunculus*. In none does it become very highly developed on account of the small size of the embryo, but in the larger forms, such as *Delphinium*, it is easily recognizable.

The tissue of the embryo is composed of thin walled cells much smaller than those of the adjacent endosperm, and possessing large, compact nuclei, which stain dark with hematoxylin giving the whole embryo a darker color than the endosperm. The cells are smaller in the vicinity of the plerome. The size of the nuclei remains, however, almost constant throughout each embryo.

The Endosperm.

The endosperm occupies by far the greater portion of the seed in all species of the order. In all species studied the embryo occupies less than one-fourth of the endosperm.

Here, as in most other plants, the endosperm consists of thin walled cells, which in outline are mostly irregularly hexagonal from compression, but vary to oblong, rectangular, square, or various other figures. The size of the cells varies greatly. Those immediately surrounding the embryo are but little larger than its cells ; but in going toward the circumference of the seed they become gradually larger until those at the chalazal end are from eight to ten times as large, and equal in size any other parenchymatous cells in the seed. The relative size of these cells in the different species is so nearly the same, that a separate discussion of them is not necessary.

Just inside the inner seed coat and surrounding the endosperm, is a thin layer staining purple. This represents the crushed remains of the nucellus, the portion inside the coats and outside of the embryo sac in the ovule. In some genera it becomes almost or quite obsolete ; in others it is represented by square thin walled cells, and in many it is thickened and brown in color in the vicinity of the micropyle and chalaza. (Pls. IV–VIII.)

The function of the endosperm, in all plants where it occurs, is to act as a store house of food for the young seedling from the time of fertilization until the seed has germinated and is old enough to take care of itself. This food occurs in two principal

forms, as starch or protein. The latter is by far the most common, and is especially predominant among the Dicotyledons, where the seeds often contain no starch at all. As starch is less easily appropriated to the use of growing organs than protein matter, this may be an adaptation in the higher plants to serve a particular purpose.

In the order *Ranunculaceæ* the cells contain only protein matter, starch being entirely absent. The protein occurs in the form of aleurone grains closely packed within the cell and varying in size from small in *Coptis* to very large in *Aquilegia*.

As to the size of the grains the genera may be roughly divided into two groups, as follows :

1. Large — *Aquilegia*, *Anemone*, *Clematis*, *Xanthorrhiza*, *Adonis*, *Hepatica*, *Hydrastis*, *Isopyrum*, and most *Ranunculi*.

2. Small — *Caltha*, *Coptis*, *Pæonia*, *Delphinium*, *Aeonitum*, *Actæa*, *Helleborus*, and *Thalictrum*.

This size varies greatly in the same cell, especially among the larger forms. The larger grains are mostly oval, while the smaller are globose. The latter are slightly angular in some species (e. g. *Coptis*). These grains are embedded in a ground mass for the most part slightly granular as in *Isopyrum* and *Actæa*, but more homogeneous in *Aquilegia* and *Ranunculus*. With hematoxylin they stain darker purple than the ground mass and also darker yellow with iodine. The contents of the grains are generally homogeneous, there being no crystalloids or globoids. This is especially the case in *Aquilegia*, but in the larger grains of *Anemone Pennsylvanica* there are numerous spherical granules. These are also found in *Isopyrum*, *Thalictrum*, and *Adonis*, but in the latter case they are mostly irregular.

With hematoxylin stain on alcoholic material the general color produced is light purple, which contrasts with the dark purple of the highly nucleated embryo. The cell wall remains uncolored, but the ground mass is slightly tinged, and the aleurone grains are still darker. The nucleus assumes the regular dark purple color. Iodine gives the cell contents a deep yellow color, which is darker in the aleurone grains and lighter in the ground mass. So far as observed, the cell wall remains uncolored with iodine except in *Pæonia* where it becomes deep blue like starch.

There is one peculiar feature of the endosperm which yet re-

mains to be described. In every case that I have observed, there is a portion in the vicinity of the embryo where the cells contain no protein or other matter in the ripe fruit. In fact, they are empty except for an occasional nucleus. The delicate cell walls have collapsed to some extent, so it is difficult to distinguish their exact outline. I have observed this peculiarity of structure in some other plants, especially of the order *Umbelliferae*. The empty cells, of course, take no stain with hematoxylin, and hence appear as an oval or elliptical light colored spot in the micropylar end of the seed, with the embryo embedded in it. It never reaches below the end of the hypocotyl, but extends above the cotyledons to some distance. Its outline is mostly very distinct and abrupt, sometimes fading slightly at the upper margin. The relative size and position of the spot may be seen in the plates. It is rather difficult to see what purpose this serves or why it came to be there, but I think the following is a reasonable explanation. As stated in many text books, the endosperm is formed and stored with food immediately after fertilization. Then, as the embryo grows it absorbs the nutriment from the surrounding cells. Sometimes the whole endosperm is absorbed, when we have an exalbuminous seed. In the *Ranunculaceae* this growth progresses very little before the seed matures, but notwithstanding this, some food has been abstracted from the adjacent cells, and thus the light empty space is formed.

INTEGUMENTS.

There seems to be some confusion as to how many integuments may be recognized in the order, different authors stating the number as one or two in the same genus. Prantl (61) says there is one integument in *Helleborus*, *Leptopyrum*, *Anemone*, *Clematis*, *Ranunculus*, *Myosurus*, *Oxygraphis*, while all others possess two. Of the above named genera I have studied the mature seeds of *Helleborus*, *Anemone*, *Clematis*, and *Ranunculus*. It is very difficult to establish the exact boundaries of the two coats in the achene forms except by a study of the developing ovules. I have had an opportunity to study these only in *Anemone*, *Clematis*, and *Ranunculus*, in all of which I find the statement of Prantl to be true. The outer coat seems to

have become obsolete in all these genera. In the mature fruit *Helleborus* presents all the features of the seeds which have two coats, and I shall provisionally describe it as having them both, although future investigation of the ovule may possibly lead to a different conclusion.

Inner Integument or Inner Seed-Coat.

This consists uniformly of two parts, although one of them often becomes nearly obsolete. (Pl. VII, 56.) The outer layer is extremely thin, and consists of compressed parenchyma, staining purple with hematoxylin, and only distinctly visible at the micropyle where it becomes thickened. In most species it can be recognized all the way round, especially when a high power is used. It consists of about one row of very thin walled cells, for the most part united firmly with the outer coat, and distinct from it only at the collar of the micropyle, where it forms an enveloping sheath to the firmer tissue within.

The inner layer is by far the most important for classification and study as it presents the least variation. It consists of a single layer of cells which are normally thick walled on the inner side and ends, and thin on the outside. In color it varies from pale yellow to dark brown, being brown in a majority of the genera. The thickened wall presents transverse striations which are either prominent and extend into the cell cavity as acicular projections, or grade away to markings scarcely distinguishable with the highest powers. These striations are always more prominent in the lighter colored walls.

The lateral aspect of the cells is square, but when looked at in the plane of the coat, the outlines are various, and depend upon the genus in hand. They may be so thin and flattened that the lumen is entirely destroyed, or oblong with a narrow lumen, or even square. In this latter case the whole cell would be cubical. As a rule the cells are shortened and thickened in the vicinity of the micropyle, and hence they may be more easily studied in that region. The accompanying plates, I think, will help to illustrate these forms.

This layer is always thickened at the micropyle, but in some cases more than in others. While only slightly thickened in the

achene forms, in the pods it is elongated into a cylinder passing, in most cases, to the surface of the seed. This I have termed the collar of the micropyle. (Pl. VII, 56.) In the center of this tissue there is generally a trace of the former tubular canal of the micropyle, which is more distinct in the generalized forms.

I will now give a synopsis of the characters of the inner integument in the genera studied.

Coptis, Outer layer distinct. Inner layer very thin, yellowish white, cells oblong, lumen obsolete from excessive thickening of the inner wall, wall strongly striated. (Pl. IV, 42.)

Xanthorrhiza, Outer layer present at the micropyle. Inner layer slightly thicker than in *Coptis*, yellowish white, cells oblong, lumen obsolete, walls strongly striate, coat much as in *Coptis*. (Pl. IV, 41.)

Isopyrum, Outer layer distinct, greatly thickened at the micropyle. Inner layer almost obsolete; scarcely visible except at the micropyle. (Pl. IV, 39.)

Helleborus, Outer layer distinct. Inner thin, very dark brown, cells short oblong, lumen small, striations not obvious. (Pl. V, 48.)

Caltha, Outer layer not prominent. Inner layer very thin, brown; cells elliptical, lumen obsolete, no distinct striations. (Pl. VI, 52.)

Hydrastis, Outer layer prominent. Inner layer very thin, brown, scarcely distinguishable, cells indistinct; walls of equal thickness, lumen obsolete, no striation. (Pl. IV, 37.)

Actæa, Outer layer distinct. Inner layer thin, brown; cells oblong, walls of equal thickness, lumen narrow, striations indistinct. (Pl. VI, 50.)

Aquilegia, Outer layer indistinct. Inner layer thin, brown; cells oblong, lumen obsolete, inner wall very thick, strongly striated, outer nearly obsolete. (Pl. IV, 40.)

Aconitum, Outer layer indistinct. Inner layer medium, dark brown; cells square, walls thickened, marked with coarse, transverse ridges. (Pl. VII, 55.)

Pæonia, Outer layer well developed. Inner layer very thin, dark brown; cells scarcely distinguishable, no evident striations. (Pl. IV, 38.)

Nigella, Outer layer indistinct. Inner layer thick, light brown;

cells oblong, walls slightly thickened, lumen rather large, striations not evident. (Pl. IV, 43.)

Ranunculus, Outer layer well developed. Inner layer thick, brown or yellow; cells short or long oblong, lumen large or small, walls of equal thickness, or inner much thicker in yellow forms, always striate. (Pl. VII, 54, and VIII, 58.)

Adonis, Outer layer indistinct. Inner layer very thin, dark brown; cells indistinct, lumen narrow, walls of equal thickness, no striations. (Pl. VII, 53.)

Thalictrum, Outer layer well developed. Inner layer medium, dark brown; cells oblong, lumen distinct, inner wall thick striate. (Pl. V, 44, 45.)

Clematis, Outer layer distinct, of several layers of cells. Inner layer thick, pale brown or colorless, cells square or short oblong, lumen small, inner wall very thick, strongly striate, outer very thin. (Pl. VI, 51.)

Anemone, Outer layer distinct, of several layers of cells. Middle layer thick, deep brown; cells oblong, lumen small. Inner wall very thick, granulate-striate, outer wall thin. (Pl. V, 47.)

Hepatica, Outer layer distinct, of few or several layers of cells. Inner layer very thin, colorless; cells indistinct; outer wall nearly obsolete, inner strongly striate. (Pl. VI, 49.)

Outer Integument.

Next in order in considering the parts of the seed, we come to the outer integument or outer seed-coat. As before stated, this part is connected more or less closely with the inner coat by means of the outer parenchymatous layer of the latter; but it may readily be distinguished from it in the collar of the micropyle of the pod forms. Being the outer covering of the seed in all pod species, and the one coming in closest contact with external objects, it is naturally much modified to form a protective covering for the seed. This is accomplished by the thickening of certain layers of cells. Again, since it is the only part of the seed coming in direct contact with the plant's environment, we should look here for the greatest variability; and this is the case, the outer coat is the most variable portion of the whole seed.

For this reason its characters are not so valuable for the study of ordinal relationships as are those of the inner coat.

This coat consists, in all cases, of two layers. The outer layer consists of one row of cells. These are generally laterally compressed and their walls much thickened. The walls or cavities contain the coloring matter which gives the characteristic color to the seeds, and the outer wall is generally convex, forming papillae on the surface. This layer is extremely variable, sometimes being reduced to small cells which are square or oblong with rather thin walls and staining purple (*Caltha*). In all the pod forms these cells bend in around the collar of the micropyle so as to line the orifice, except in *Pæonia* where they are continuous over the micropyle.

The inner layer is composed entirely of parenchyma containing dried protoplasmic bodies, sometimes chlorophyll grains, and less often nuclei. It is thickened in the region of the raphe, the vascular strand of which always passes through its tissue.

The following is a more detailed description of the coat as it occurs in the different genera:

Coptis, First layer, thick, purple; cells laterally compressed, inner wall thin; outer white, thick; sides thick to middle; lumen purple, distinct.

Second layer, thick, of turgid parenchyma cells, raphe strand minute. (Pl. IV, 42.)

Xanthorrhiza, First layer, thick, dark purple; cells somewhat compressed; outer wall thick, thickly cutinized.

Second layer, a thin layer of compressed parenchyma, dark purple like outer layer. (Pl. IV, 41.)

Isopyrum, First layer, thick, purple, thicker at chalaza and micropyle; cells strongly laterally compressed; walls thickened only on outside and sides to middle; lumen distinct, some of the cells bearing short clavate hairs.

Second layer, a thin layer of parenchyma whose inner cells are compressed; cell contents dried protoplasm; raphe strand very large and well developed. (Pl. IV, 39.)

Helleborus, First layer, very thin, much thinner at raphe, dark purple; cells elongated, broader than thick; lumen small; cell walls enormously thickened, on outside purple; surface cutinized, yellow; clavate hairs few in vicinity of raphe; cutin granulose.

Second layer, very thin ; cells compressed ; expanded into the inflated raphe ; strand minute. (Pl. V, 48.)

Caltha, First layer, thin, purple ; cells broader than thick ; walls thin, thickened only slightly on outside.

Second layer, very thin, thickened above into a mass one-third size of endosperm, contains some protoplasm. (Pl. VI, 52.)

Hydrastis, First layer, thick, dark brown ; cells very much laterally flattened ; walls, except inner, very much thickened, sides irregularly so ; outer wall cutinized, cutin granulose.

Second layer, thick, of firm parenchyma ; raphe strand large ; coat thinner along raphe groove. (Pl. IV, 37.)

Actæa, First layer, thick, brown ; cells large, slightly latterally compressed ; walls uniform, moderately thick.

Second layer, of thick parenchyma ; cells oblong, thicker at the angles of the seed ; raphe strand small. (Pl. VI, 50.)

Aquilegia, First layer, thick, dark blue ; cells laterally compressed ; outer walls and sides to middle, thick, inner thin.

Second layer, moderately thick ; a cavity at chalaza ; raphe strand prominent. (Pl. IV, 40.)

Delphinium, First layer, very thin, purple ; cells broader than thick ; outer wall very much thickened, purple, with yellow granulose cutin layer ; inner wall very thin.

Second layer, very scanty, few cells around interior, angles empty ; raphe strand very small, between angles. (Pl. V, 46.)

Aconitum, First layer, very thin, purple ; cells broader than thick ; outer wall and sides to middle very thick ; inner thin, covered with very minute papillae.

Second layer, as in *Delphinum* ; raphe strand minute, in middle of larger wing. (Pl. VII, 55.)

Pæonia, Three layers, the second corresponds to the first of other genera. Micropylar orifice completely closed.

First layer, one cell thick, covering the seed, thin, thick at the chalaza, cells square or slightly compressed ; walls dark reddish brown ; outer and inner thickened, sides thin and corrugated ; layer of light purple cutin on surface.

Second layer, very thick, yellow ; cells strongly laterally compressed ; no lumen ; very thick walls ; tissue containing crystals of calcium oxalate.

Third layer, thick, parenchyma cells compressed ; raphe strand

small in a sheath of brown tissue; no external raphe ridge on seed. (Pl. IV, 38.)

Nigella, First layer, medium, purple; cells triangular with one angle outward forming papillae; walls, except outer, rather thin.

Second layer, obsolete except some crushed parenchyma at the angles; raphe strand very small, in an angle. (Pl. IV, 43.)

Ranunculus, Coat obsolete from the first; raphe strand always distinct, often large; micropyle in most species not covered. (Pl. VII, 54, and VIII, 58.)

Adonis, Coat very thin, the two layers not distinct except at the thickened raphe, where the outer takes a deeper stain; raphe strand small; coat continuous at the micropyle. (Pl. VII, 53.)

Thalictrum (*T. dioicum*), First layer, medium, purple; cells oblong rectangular, the walls somewhat thickened; cell contents protoplasmic remains; inflated at micropyle.

Second layer, irregular crushed parenchyma; raphe strand small. (Pl. V, 44, 45.)

Anemone, Coat obsolete from the first; a strand in each angle of the seed. (Pl. V, 47.)

Clematis, Coat obsolete; raphe strand more prominent micropyle nearly covered. (Pl. VI, 51.)

Hepatica, Coat obsolete; micropyle mostly open; raphe strand very small. (Pl. VI, 49.)

THE OVARY.

By the term ovary here I mean the walls of the carpel which enclose the ripe seeds. The structure and modifications of this wall contributes some very important evidence in the study of generic relationship. I will, therefore, present the following notes on this portion of the fruit.

External Features.—In general outline the carpels vary considerably. In *Coptis*, *Xanthorrhiza*, *Actæa*, *Isopyrum*, *Anemone*, *Thalictrum* and *Clematis* they are either broadly or narrowly fusiform; but in *Aquilegia*, *Caltha*, *Delphinium*, *Aconitum*, *Pæonia*, *Nigella*, and *Ranunculus*, they are more unsymmetrical, the dorsal margin being nearly straight, while the ventral is convex. This is carried to the extreme in *Ranunculus*. *Adonis* differs from the general type of *Anemone* only in having a more abrupt style. *Myosūrus* is more like *Ranunculus*.

The carpels are either smooth (*Coptis*, *Ranunculus*), rugose and warty (some species of *Ranunculus*), veiny (*Aquilegia*, etc.), longitudinally ribbed (*Thalictrum*, etc.), or hairy (*Anemone*, etc.).

Since the walls of the achene permanently invest the seed, and the achene forms are probably the most specialized, we should expect to find more provisions for dissemination and planting here than in the pod ovary. This is exactly the case. Dissemination is favored in *Clematis*, by the hairs on the elongated styles, and in *Anemone* by hairs on the ovary itself. *Ranunculus* has for the most part failed to provide any disseminating organs; still in some species, the style has assumed the form of a hook which may catch in the fur of animals. In the more generalized or degenerate achenes we should expect to find these provisions less developed; for example, in *Hepatica*, there are no evident provisions at all for dissemination, but there are some which may aid in planting the seed in the proper position. The embryo being at the upper end of those achenes there should be some provision for bringing this end first in contact with the soil. In *Hepatica* this is secured by the fruit being tapering above, and a peculiar structure of the wall mentioned below. The ribs of *Thalictrum* may serve to guide the achene in assuming an erect position although there is nothing to determine which end shall be toward the earth.

Structure of the Wall, There are two distinct layers to be recognized in the carpellary walls. First, the inner epidermal layer lining the cavity of the ovary; second, the remaining parenchyma outside of the first layer. These undergo many modifications in the different genera, so I shall treat each one as it appears in different parts of the order.

Inner Layer, The cells comprising this layer are always elongated, mostly square or circular in cross section, and generally provided with thick walls. Indeed, they have the appearance of wood cells, except in a few genera where they are not thick walled and where the outline is more sinuous and the ends more truncate.

Coptis, Cells much elongated transversely, outline slightly wavy, ends tapering or truncate; walls very slightly thickened, yellow, dotted.

Caltha, Cells transversely elongated, outlines sinuous, ends truncate or tapering; inner walls slightly thickened, purple not truncate.

Aquilegia, Cells rather large, transversely elongated, outline regular, ends symmetrically tapering ; walls mostly slightly thickened, dotted.

Trollius, Cells transversely elongated, large, truncate or tapering ; walls slightly thickened, dotted.

Xanthorrhiza, Cells longitudinally elongated, yellow thick walled.

Hydrastis, Cells transversely elongated, parenchymatous, filled with sap and protoplasm.

Aconitum, Cells transversely elongated, thin walled, yellow, not dotted.

Delphinium, Cells transversely elongated, colorless, inner wall slightly thickened, not dotted.

Actæa, Cells purple, thin walled, scarcely distinguishable from the other layer. In *Cimicifuga*. the cells are transversely elongated ; walls slightly thickened, yellow dotted.

Thalictrum, Cells elongated longitudinally, slightly laterally compressed, colorless, inner wall and sides very thick, outer thin ; lumen small. (Pl. V; 44, 45.)

Hepatica, Layer very thick ; cells much elongated longitudinally, truncate or tapering, laterally compressed, sometimes showing transverse septa in cross section ; thick walled, yellow, dotted. (Pl. VI, 49.)

Clematis, Cells very much longitudinally elongated, much compressed, small, ends tapering ; walls thick especially on inside ; colorless, dotted, (Pl. VI, 51.)

Anemone, Cells much elongated, ends mostly truncate, slightly compressed, colorless ; walls very much thickened on inside and sides, thin on outside, not dotted. In *A. Pennsylvanica* this layer is several cells thick, the cells are small and walls equally thickened, thickly dotted. (Pl. V, 47.)

Ranunculus, Cells transversely elongated, square, walls equally thickened, colorless and dotted. (Pls. VII, 54, and VIII, 58.)

Adonis, Cells in the species studied longitudinally elongated, square in cross section ; walls thick and dark brown.

The remaining genera were not studied in this respect, owing to lack of material.

This is the layer which has been modified especially for strengthening and hardening the walls of the achene. From the

descriptions it will be noticed that it is comparatively thin in all pod forms, but there is not an achene which does not have these cells thick walled. This process of thickening is carried to the extreme in *Hepatica* and *Anemone Pennsylvanica*, where the layers of cells are increased in number. All that the pod requires is to be held in shape. It is only in rare cases that any other part of the ovary wall becomes modified for the purpose of protection.

Outer Layer. This layer occupies all of the remaining portion of the carpellary wall and is also modified but these modifications are not so numerous nor so abrupt and distinct as in the inner layer, for which reason a special description of its form in each genus will not be necessary. All the modifications that I have observed are related to distribution rather than protection ; the only exceptions being in *Ranunculus* and *Adonis*, where the cells are longitudinally elongated, thickened and dotted like the inner layer, except the outer row of cells in each case which still remains parenchymatous.

The typical structure of the layer as found in the pod forms is one consisting of several rows of parenchyma cells. This is extremely thin in *Coptis*, *Xanthorrhiza*, *Aconitum*, and *Delphinium*, but is thicker in all other pod genera. In these cases the pod aids neither in dissemination nor in planting, but in *Actæa* and *Hydrastis*, the layer becomes very thick and the thin turgid cells are well filled with cell sap and protoplasm, thus forming a berry. At the same time a red pigment is produced which renders them more attractive. The berry is rare in the order *Ranunculaceæ*, being found only in those two genera. The outer layer in the pod forms is traversed by many fibro-vascular strands under the nerves which appear on the surface. Passing to the achenes, we find the layer modified to aid dissemination by means of wind. The hairs already noticed serve this purpose. In *Thalictrum* the layer is thickened at each rib and a strand passes up through each. In *Clematis* and *Anemone Virginiana* it is equally thickened throughout. In *Anemone Pennsylvanica* it is greatly thickened at the dorsal and ventral margins forming a wing, but in *Hepatica* it is reduced to a layer of one or two rows of cells. As before stated, the cells become thick walled only in *Ranunculus* and *Adonis*. In the former they are colorless, in the latter dark colored.

The outer layer of parenchyma cells presents a feature in some of the achenes which is peculiar and the cause of which is difficult to explain. In *Hepatica*, *Clematis Virginiana*, *C. verticillaris* and *Anemone Pennsylvanica* the cells are slightly elongated, tapering at each end and overlap like shingles on a roof, the free edge pointing toward the base of the achene, and causing a slight serration of the surface in that direction. The hairs are non-septate and arise from between the other cells. While in the tissue they necessarily point downward, reaching the surface they make a sharp bend and point toward the style. This is most prominent in *Hepatica* and *Anemone Pennsylvanica*. In *A. Virginiana* the same cells point upward and are very prominent. The hairs, therefore, are straight.

Position of the Ovules. A few words might be said as to the position of the ovules in the ovary. In the pod forms they are borne on two placentæ formed from the incurved margins of the carpellary leaf, in such a position that the raphes of the two rows come back to back with the micropyle outward and slightly ascending, but in some species they are pushed together into one row. In most pod forms the seeds are numerous, but in *Xanthorrhiza* and *Isopyrum biternatum* they are reduced to two. In *Callianthemum* there is only one seed left at fruiting time. *Hydrastis Canadensis* has only two seeds and these spring from the placenta at the side or towards the base, but in *Xanthorrhiza* they spring from the top of the pod, a feature which I shall endeavor to explain later.

It is well known that among the achenes the seeds may be classified into two groups as to their position.

1. Suspended, that is attached at the top of the ovary, in *Clematis*, *Anemone*, *Thalictrum*, *Hepatica* and some species of *Adonis*.

2. Erect, that is, springing from the base of the ovary, in *Ranunculus*, and some species of *Adonis*. *Myosurus* presents an intermediate form.

Venation. If we examine the carpels of different species of *Ranunculaceæ*, we shall see that some possess strong venation while others are nearly veinless. Under this topic I shall describe some of the forms which the venation assumes.

I have already stated that there is in every carpel a vein running along the dorsal, and one along the ventral margin. The dorsal

never contains more than one vascular strand. The ventral in some species contains one, in others two. The pod forms all have two strands running from the base to the top ; so also does *Ranunculus*, but in those fruits with suspended ovules, the strand is single up to the funiculus, from which point on it is double. In all of the pod forms examined with the exception of *Coptis trifolia* and *Isopyrum biternatum*, there were also cross veins, some simple and some branched much like the veins of a leaf ; but instead of springing from the dorsal or mid rib, they spring from the two ventral strands and are ascending from it, instead of descending as they naturally should. Moreover, there is generally a space between the dorsal vein and the ends of these cross veins. The ventral strands unite with the dorsal at the style. In *Isopyrum*, in addition to the two primary ribs there are at least two others running longitudinally with no evident cross veins. The two primary ribs are always present in the achenes, and in only one genus studied were there any others. These were the longitudinal ribs of the genus *Thalictrum*.

In *Aquilegia* the cross veins bend up at the dorsal side and anastomose forming an ascending net work, and the dorsal rib is no larger than these ascending branches. In *Coptis trifolia* there are two extra lateral veins extending from the base to near the middle of the carpel, and which in other species of the genus become ribs.

RELATION OF ACHENE TO POD.

In the foregoing pages I have shown that the ovules in the achene and pod forms occupy different positions, and what is more important, that the elongated cells of the inner ovarian layer together with the ribs tend in different directions in different genera. In the pod whether it be short or elongated, the secondary veins mostly run perpendicularly to the dorsal and ventral ribs ; and the inner cells run transversely, except at the base where they are somewhat ascending. But in the achenes, with the exception of *Ranuuculus* the secondary ribs run longitudinally. The inner cells are also longitudinal, almost exactly so in every case examined except *Ranunculus*. In *Ranunculus* the cells remain transverse and in *Xanthorrhiza* they are vertical as in *Anemone*.

We shall see how nicely these contradictory features harmonize in the following theory of achene formation in this order. In the *Anemone* group the number of ovules has been reduced to one, while the ovarian cavity elongated below and contracted above. In *Ranunculus* the ovules were reduced to one, while the elongation, if any, was above. As mentioned above, in all the pod forms the inner cells tend to be vertical at the base, as do also the ribs. Suppose the ovarian cavity pushed down into this base, at the same time contracting above ; the whole cavity would necessarily be lined with these longitudinal cells, the placenta, remaining normal would be left at the top of the cavity and the seed would be suspended. This is further supported by the fact that the ventral strand does not fork into placental strands until it reaches the funiculus at the top of the cavity. The same thing has been accomplished in *Xanthorrhiza* by the elongation of the placental side of the ovary during the process of maturing. *Ranunculus*, on the other hand, has retained the pod characters while the ovules have been reduced in number. The placenta runs from the base to the style but is not ovule bearing above its base.

The downward extension of the ovarian cavity may arise from a lengthening of the ovary below, or it may be merely an extension of the cavity into the stipe, which exists in many present pod forms (e. g. *Coptis*), with a simultaneous contraction above into the style. That this is the case may be inferred from *Anemone* ovules up in the style above the funiculus of the perfect ovule. (Prantl, 61.)

The view that this portion answers to the true placental part of the ovary is also strengthened by the fact that a cross section of the style in some species (*Hepatica*) shows not only the two strands, but an evident slit or fissure between them answering to the line of dehiscence of the pods. This same feature may be seen in the body of the achene of *Ranunculus septentrionalis*, but in the other higher forms of *Ranunculus* it is not evident. It is, therefore, evident that *Ranunculus* is much closer related to the pod forms as far as the fruit is concerned than is the *Anemone* group. Indeed, the two groups seem to be offshoots of entirely different types of pod genera. Prantl (61) mentions the fact that the ovary has been extended downward in the

achenes having a suspended ovule, but he gives no account as to how it has been brought about.

METHODS.

Those fruits native in Central New York were collected during the summer as they ripened, and were placed immediately in 60 per cent. alcohol. In my opinion seeds preserved in this way show their parts better and in a more natural manner than do those that have been dried. Representatives of genera not native here, all came as dried fruits. In order to make them soft enough to section, they were soaked for about twelve hours in warm water. The softened seeds, both fresh and from these dried specimens, were then dehydrated with 95 per cent. alcohol by means of a Schultzes Apparatus. (Thomas, Collodion method in Botany, Proc. Amer. Mic. Soc., 1890) for about seven days, it requiring considerable time to abstract the water from the interior of the seed. The material was now placed in 2 per cent. collodion (2 gms. gun cotton, 50 c.c. 95 per cent. alcohol, 50 c.c. ether) where it remained about four days. At the end of that time 5 per cent. collodion was poured on it. Two days later the collodion with seeds in it was poured into a shallow paper box and there allowed to harden for a short time in air, then in 82 per cent. alcohol. From the boxes they were cut out and embedded on cork, and the same process of hardening again gone through with. With small seeds it is often very difficult to embed them in any desired position direct from the fresh collodion but when first hardened in boxes square blocks containing the seed may be cut out and placed in any position upon the cork, fresh collodion being poured over them to hold them in place.

The sections were all made upon a sliding microtome and a rather narrow thick edged section knife, was used. The edge of the larger knives is too thin to be used in cutting firm seed tissue. The sections were all cut in alcohol. For the smaller seeds a very quick stroke of the knife seemed to give better results, while larger seeds required a steady slow stroke. The thin layers of collodion containing the sections, after being placed upon the slide in the desired position, were cemented to it by allowing small drops of ether to flow over

them. Each drop should evaporate before application of the next so that the sections may not be floated out of place. Hematoxylin was found to give the best results as a staining agent. The contrasts brought out by it, between the endosperm, embryo, parenchyma, and sclerenchyma were very marked. After washing the sections with water the stain was applied. When the color was deep enough the superfluous stain was washed off with water, sections dehydrated with 95 per cent. alcohol, cleared (2 parts carbolic acid and 3 parts turpentine) and mounted in xylol balsam, (dried Canada balsam dissolved in xylol).

In all cases serial sections of the seed were taken in three planes:

1. Cross section.
2. Longitudinal section through raphe.
3. Longitudinal section perpendicular to the plane of the raphe.

In case of pod forms, separate sections of the pods were made.

GROUPS.

The genera possess certain features in connection with the fruit which throw them into several well defined groups. At least eight may be distinguished. The following is a discussion of these, beginning with the pod forms:

Group I. Consisting of *Coptis* and *Xanthorrhiza*. These both possess an inner coat which is white and coarsely striate. An outer coat of compressed cells, no raphal wing, and a similar outline. The form and structure of the ovary is similar, except that the cavity of *Xanthorrhiza* has become oblique through the lengthening of the placental side.

Group II. Consists of *Caltha*, *Actæa*, *Delphinium*, *Aconitum*, *Nigella*, and *Helleborus*. These agree in having an outer coat with outer layer of thin cells from elongated becoming convex and at length compressed. Inner layer of loose parenchyma or absent. Inner coat thick or varying to thin of square or oblong rectangular cells, walls thin or the inner becomes thickened. Seeds all more or less three angled. The pods are of the same general form and the inner cells agree in being thin walled and not dotted.

Group III. *Aquilegia* and *Isopyrum*. Outer layer of the seed with compressed cells, exactly similar. Inner coat very thin, dark brown. Seeds of exactly the same form.

Group IV. *Pæonia* stands alone in having three layers in the outer seed coat and the micropyle completely closed; but the structure of the coat in *Hydrastis*, especially the character of the much compressed cells, indicates that it is somewhat intermediate between *Pæonia* and the other genera.

Group V. *Ranunculus.* Has transverse cells in the inner ovarian layer, erect seeds and unsymmetrical outline to its ovary.

Group VI. *Clematis*, *Anemone*, and *Hepatica*, which have suspended ovules and a spindle-form outline to the achene. Inner cells of the ovary colorless, cells equally thick walled, compressed and mostly with cross partitions. Inner coat light colored, thick or thin, walls coarsely striate.

Group VII. *Thalictrum.* Ovary strongly ribbed, fusiform. Inner cells nearly square in cross section, outer wall thin, inner wall thick, like a V. Inner coat of seed dark, finely or obsoletely striate. Outer coat often well developed.

Group VIII. *Adonis.* This genus has longitudinal cells in the inner ovarian layer in the species studied, and the thick walled cells of the ovary are dark red in color. The seeds are either erect or suspended.

THE VALUE OF THE FRUIT IN CLASSIFICATION.

It may be asked just what value the fruit has in classification, and how much dependence can be placed on any one of its several parts in the study of relationships. Since so little attention has been paid to its minute details by systematic botanists, what reason is there now for considering these details as valuable taxonomic characters?

Before considering this point directly it is desirable first to determine upon what value depends. In studying a group of organisms, we first endeavor to separate them into certain groups, orders, families or tribes, the members of each group showing a more or less close relationship to each other. These first groups must be few and hence the separating characters must be very broad and general and common to a very large number of forms.

If this is true these characters, according to our modern ideas of evolution of organisms, are those which existed in the progenitor of the group in question, and have remained little changed or at least recognizable in all of its descendents up to the present time. Such characters are necessarily very few. But in the subsequent division of our group into genera, then species and perhaps varieties, we constantly include fewer forms and approach nearer and nearer to the present. The separating characters may, in a similar degree, be less constant and proportionally more numerous. It follows, then, that characters for the separation of the smaller groups such as species and varieties may be drawn from any differences that exist, but those of the higher groups must be from parts proportionally less subject to variation from the lowest to the highest. The value of a character then depends upon its susceptibility to variation.

Variation in organisms is probably augmented by changes in the environment and modified by natural selection. It would seem, therefore, that those parts of the organism farthest removed from external influences are the most constant. They are not required to adapt themselves to any new conditions, and they have long ago become almost as well fitted to perform their function as it is possible for them to be. Indeed, there is always a chance that a variation along a certain line may enable the organ to function still better, but the farther the organ is removed from external influences and the longer the period of this removal, so much the longer has been the time for adaptation, and the chances of there being any such beneficial line of variation tend toward zero. All other variations would be either neutral or harmful. It is not very probable that two or more conditions can exist for any organ under which it can function equally well. At any rate, these cases are very few. Natural selection will then provide that the condition or structure best adapted to the needs of the organ shall be perpetuated. In other words, the organ will tend to remain constant. So far it has been assumed that the function remains constant, which is not always the case. Many organs perform duties which they did not formerly. In selecting organs for the study of the relationship of groups, we must also select those whose functions have remained unchanged.

The features of a plant most subject to variation through

changes in environment are habit, foliage, and parts of the flower. The latter should include the floral envelopes, surface of the seed, form and dehiscence of the carpels, and everything having to do directly with pollination and disseminatlon. These respond to all of the minute changes of their environment, which in turn are numerous.

The two most constant series of organs in a plant seem to be, first, those connected with nutrition. These comprise the general internal anatomy of the organism and are subject to possible changes in the soil and atmosphere, as also to slight variation in the function itself. Secondly, those connected with the reproduction, especially the internal parts of the seed. These are very little affected by environment, and are therefore practically constant if the needs of the process of reproduction are constant.

Reproduction among the higher plants is practically constant as shown by investigation. There is no essential difference between the way in which new plants are produced in the *Polypetalæ* and in the *Monocotyledones*. Practically the same method is used by the lower plants in their sexual methods. The process of reproduction is one wholly subjective. The production of the young embryo and the internal structures of the seed are things having very little to do with external conditions. Not till the embryo is nearly mature does it begin to show any obvious adaptations to surroundings, and these are adaptations in the size of different parts, and do not effect the method of formation. The embryo, is perhaps more variable than parts of the seed immediately surrounding it, since these never come directly in contact with the environment. If, then, it is probable that the process of reproduction is practically constant within groups of orders such as the *Polypetalæ*, and the internal parts of the seed are removed from external influences, these would seem to be the most constant elements of the plant, and features suitable for the separation of the larger groups of the *Phanerogamia*. Of course, other parts should be taken into account in the characterization of higher groups, but they should be of only secondary importance, and may act as a safe guard against error. They can be used with much more freedom in the separation of genera and species.

This idea of the value of the reproductive organs, especially their internal features in the characterization of the larger groups

is not a new one. It has been acknowledged by most of the prominent animal embryologists (Agassiz, Essay on Classification.); and in proof of its importance, embryology occupies almost a separate department of study. In botany, the primary divisions of the Angiosperms, the Monocotyledons and Dicotyledons, are characterized by features of the embryo. but farther than this the internal anatomy of the seed has been little used I am not aware that any distinguishing characters have ever been drawn from the minute investigation of the seed coats.

It was with these points in view that the foregoing detailed study of the fruit was made.

LIST OF SPECIES STUDIED.

Aconitum Napellus, L.
Actaea spicata, L. *var rubra*, Ait.
" *Cimicifuga*, L.
Hepatica triloba, *Chaix*.
Anemone Pennsylvanica, L.
" *Virginiana*, L.
Aquilegia Canadensis, L.
" *vulgaris*, L.
Adonis vernalis, L.
Caltha palustris, L.
Coptis trifolia, Salisb.
Delphinium formosum, B. & H.
Helleborus niger, L.
Hydrastis Canadensis, L.
Isopyrum biternatum, T. & G.
Nigella Damascena, L.
Paeonia officinalis, L.
Ranunculus circinatus, Sib.
" *multifidus*, Pursh.
" *abortivus*, L.
" *sceleratus*, L.
" *recurvatus*, Poir.
" *septentrionalis*, Poir.
" *Pennsylvanicus*, L. f.
" *acris*, L.
Thalictrum dioicum, L.
" *polygamum*, Muhl.
Xanthorrhiza apiifolia, L'Her.
Clematis Virginiana, L.
Clematis verticillaris, DC.

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EXPLANATION OF PLATES.

A, embryo ; B, endosperm ; C, inner integument ; D, outer integument ; E, carpellary coat ; F, micropyle.

(a) the remains of the nucellus ; (b) inner layer of the inner integument ; (c) outer layer of the inner integument; (d) inner layer of the outer integument ; (e) outer layer of the outer integument ; (f) the superfluous layer of the seed of *Paeonia* ; (g) inner layer of carpellary coat ; (h) outer layer of carpellary coat ; (i) raphe ; (j) collar of the micropyle ; (m) extra strand in *Anemone* ; (n) raphe strand.

Plates I–III are outline drawings of the seed both in cross and longitudinal sections. The cross section was made midway between the ends of the seed ; the longitudinal in the plane of the raphe. In the achene forms the carpel is also included.

Pl. I—	1, 2.	*Pæonia officinalis*, L.	x 7	diam.
	3, 4.	*Hydrastis Canadensis*, L.	x 10	"
	5, 6.	*Isopyrum biternatum*, T. & G.	x 20	"
	7. 8.	*Aquilegia vulgaris*, L.	x 20	"
	9, 10.	*Coptis trifolia*, Salisb.	x 60	"
Pl. II—	11, 12.	*Xanthorrhiza apiifolia*, L'Her.	x 40	"
	13, 14.	*Thalictrum dioicum*, L.	x 15	"
	15, 16.	*Anemone Virginiana*, L.	x 12	"
	17, 18.	*Hepatica triloba*, Chaix	x 12	"
	19, 20.	*Clematis Virginiana*, L.	x 12	"
	21, 22.	*Actaea spicäta*, L. *var. rubra*, Ait.	x 12	"
	23, 24.	*Nigella Damascena*, L.	x 12	"
	25, 26.	*Caltha palustris*, L.	x 20	"
Pl. III—	27, 28.	*Ranunculus recurvatus*, Poir.	x 15	"
	29, 30.	*Adonis vernalis*, L.	x 9	"
	31, 32.	*Helleborus niger*, L.	x 10	"
	33, 34.	*Delphinium formosum*, Boiss, & H.	x 20	"
	35, 36.	*Aconitum Napellus*, L.	x 10	"

Plates IV–VII represent portions of the seed coats in cross section. Those of the genera producing achenes show also a portion of the carpel lary wall. *Poeonia* is enlarged 135 times; all others 290 times (except No. 56).

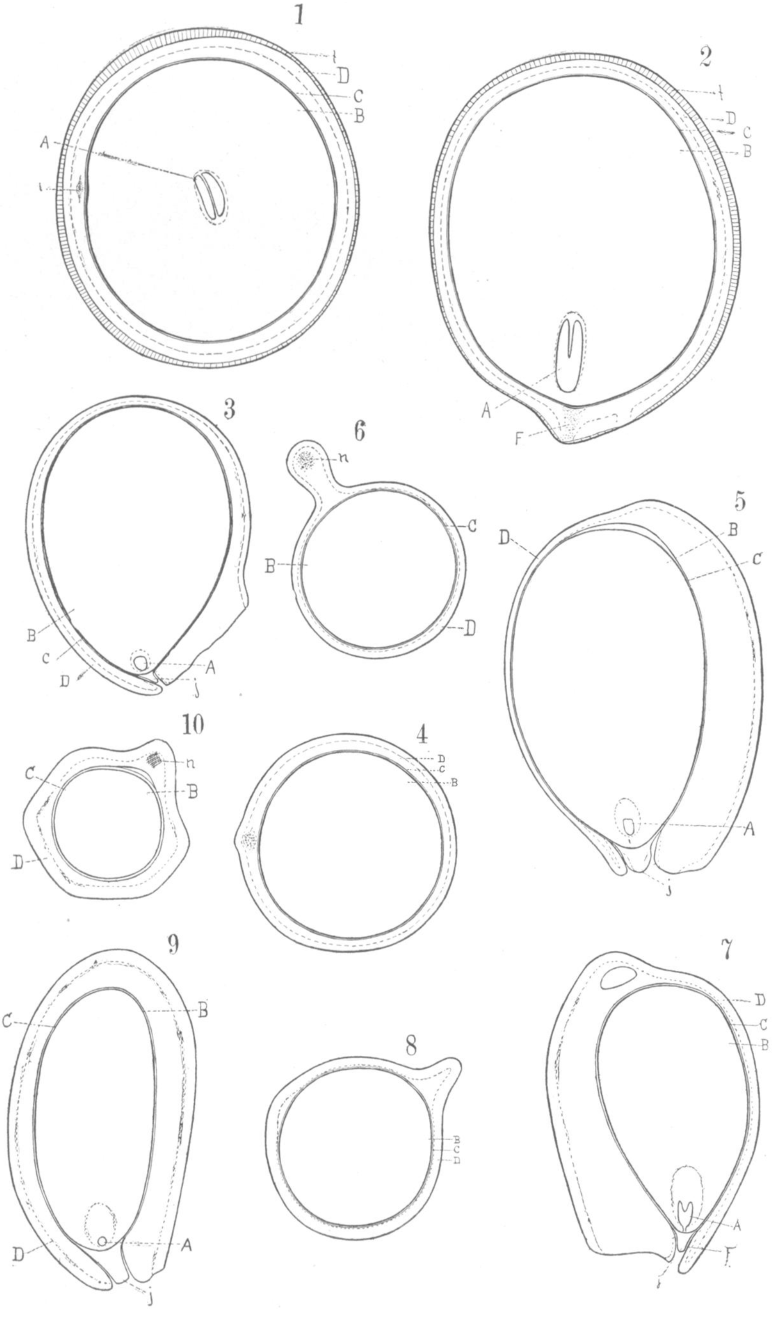
Pl. IV—37. *Hydrastis Canadensis*, L.
38. *Paeonia officinalis*, L.
39. *Isopyrum biternatum*, T. & G.
40. *Aquilegia vulgaris*, L.
41. *Xanthorrhiza apiifolia*, L'Her.
42. *Coptis trifolia*, Salisb.
43. *Nigella Damascena*, L.

Pl. V—44. *Thalictrum dioicum*, L. cross sec.
45. *Thalictrum dioicum*, L. vert. sec.
46. *Delphinium formosum*, B. & H
47. *Anemone Virginiana*, L.
48. *Helleborus niger*, L.
Pl. VI—49. *Hepatica triloba*, *Chaix*.
50. *Actaea spicata*, L. *var. rubra*, Ait.
51. *Clematis Virginiana*, L.
52. *Caltha palustris*, L.
Pl. VII—53. *Adonis vernalis*, L.
54. *Ranunculus septentrionalis*, Poir.
55. *Aconitum Napellus*, L.

Plate VIII, together with No. 56, Pl. VII, represents longitudinal sections through the micropyle in the plane of the raphe, showing especially the structure of the tissue about that point.

56. *Coptis trifolia*, Salisb.	x 135 diam.
57. *Clematis Virginiana*, L,	x 55 "
58. *Ranunculus recurvatus*, Poir.	x 135 "

PLATE I.



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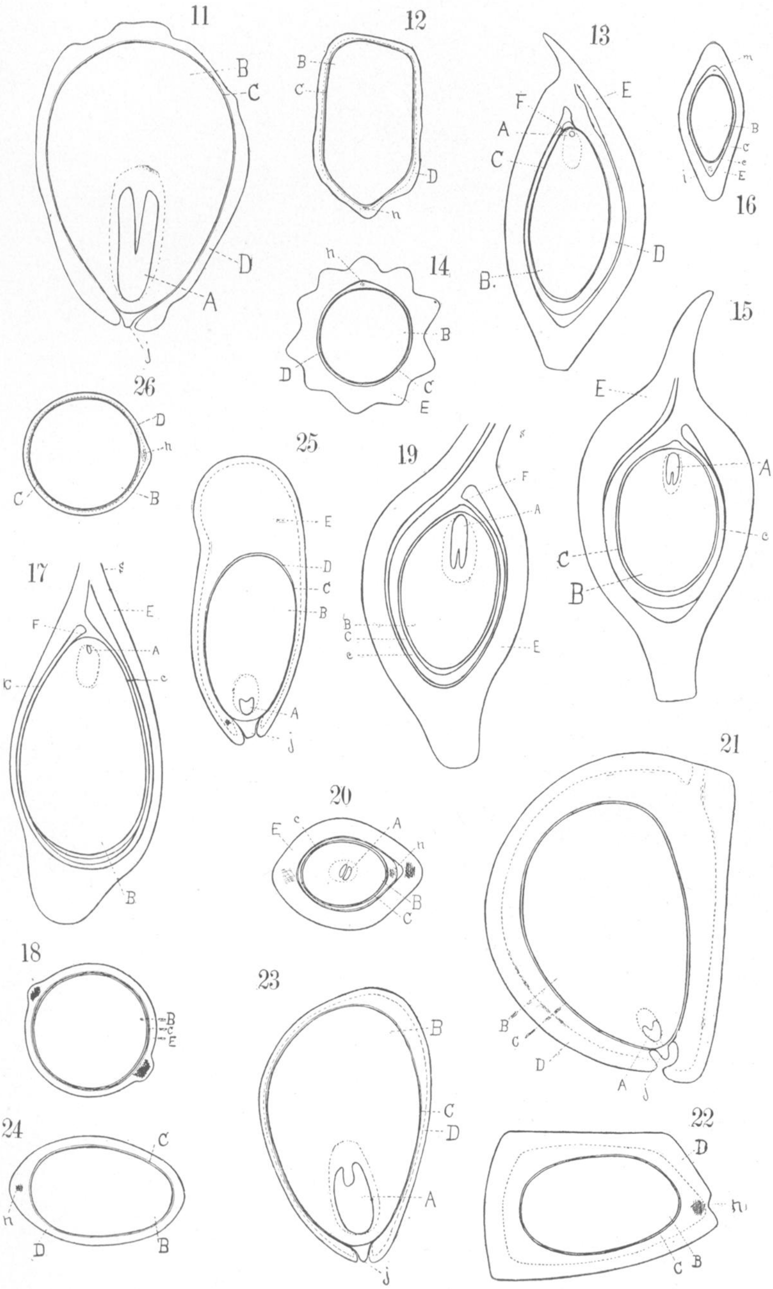
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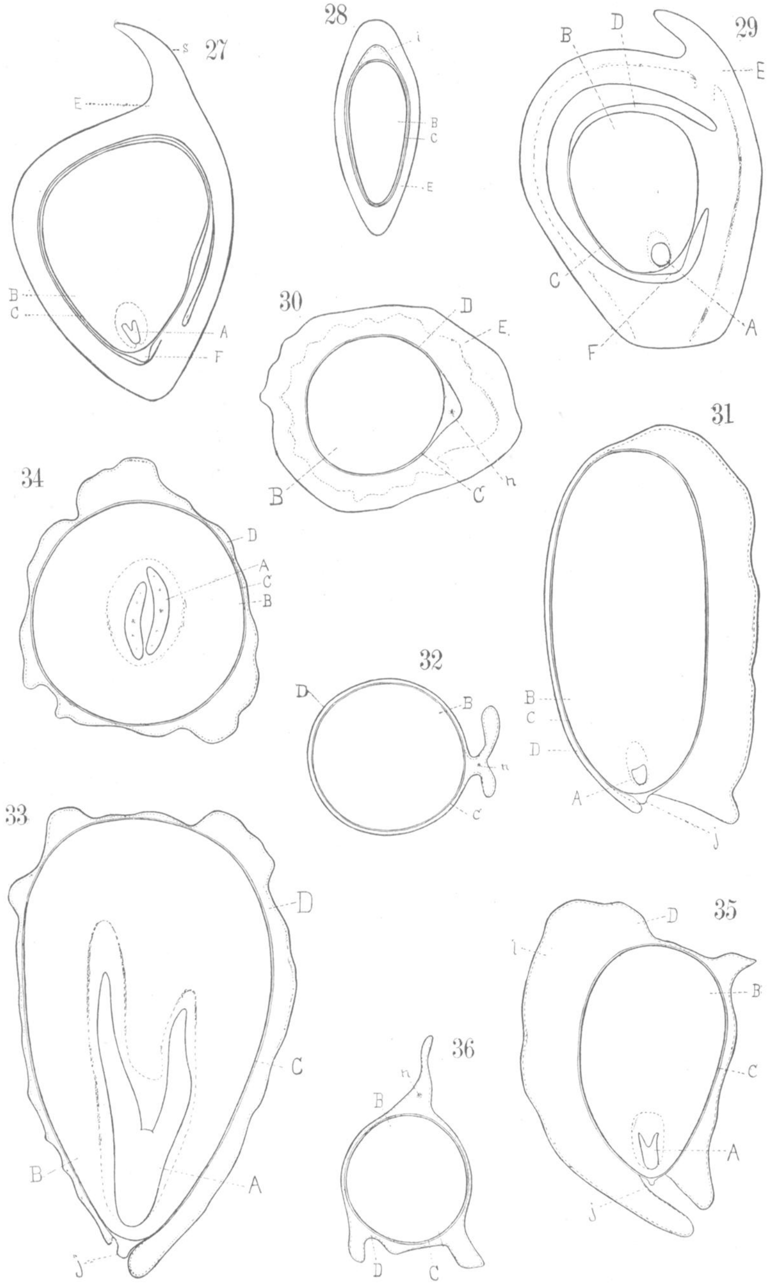

PLATE IV.

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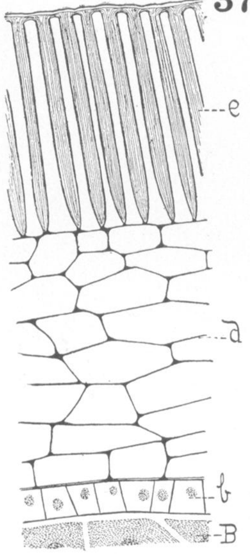

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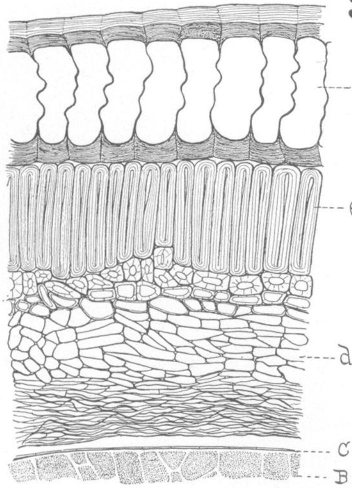

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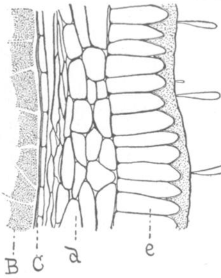

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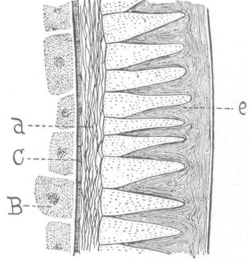

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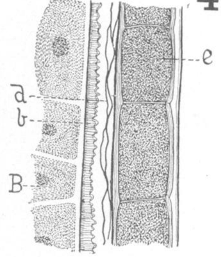

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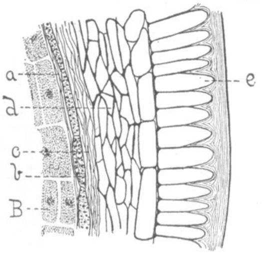

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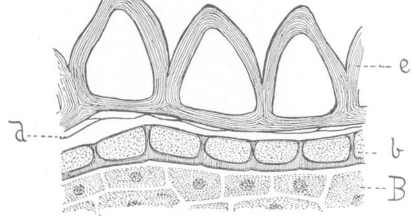

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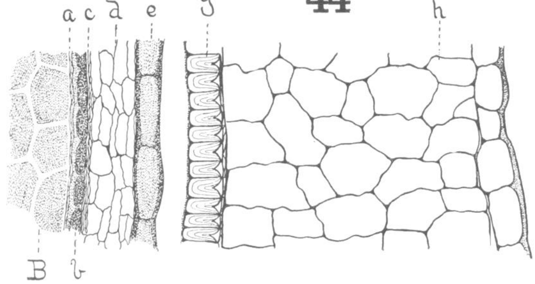

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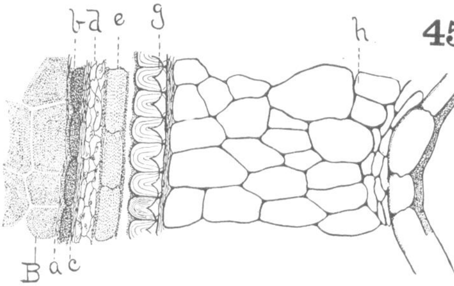

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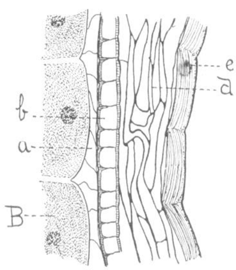

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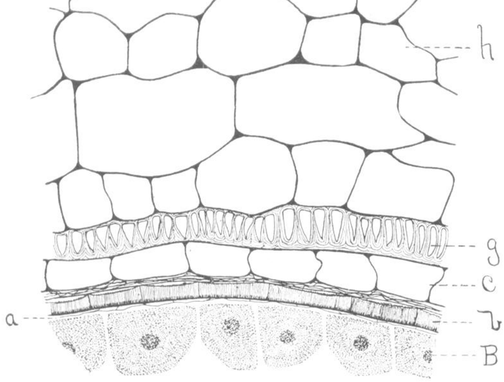

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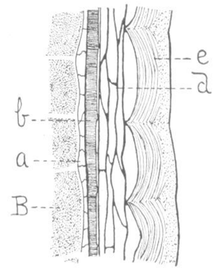

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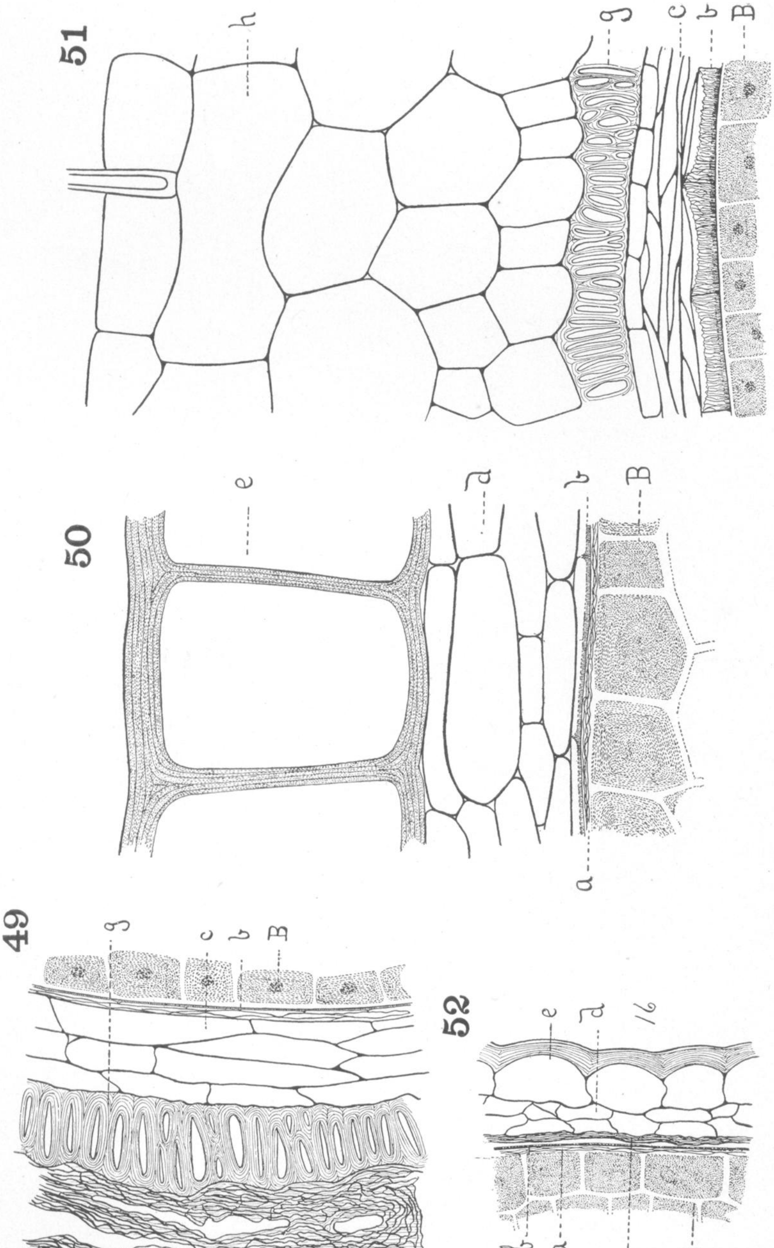

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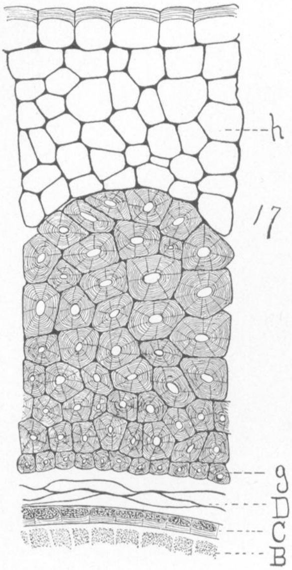

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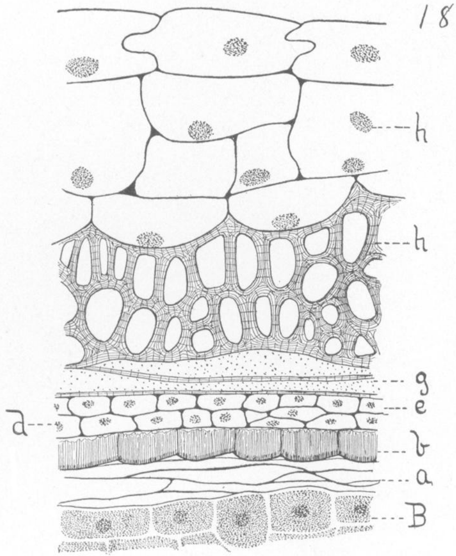

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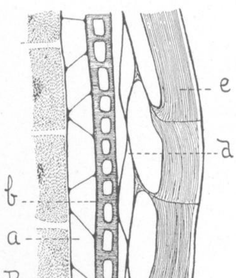

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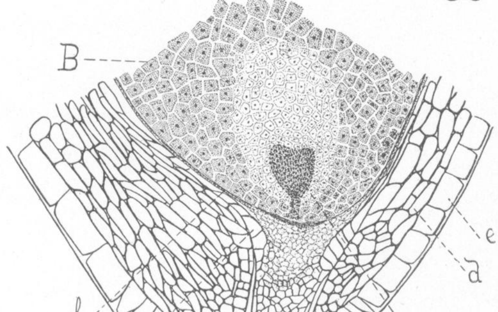

PLATE VIII.

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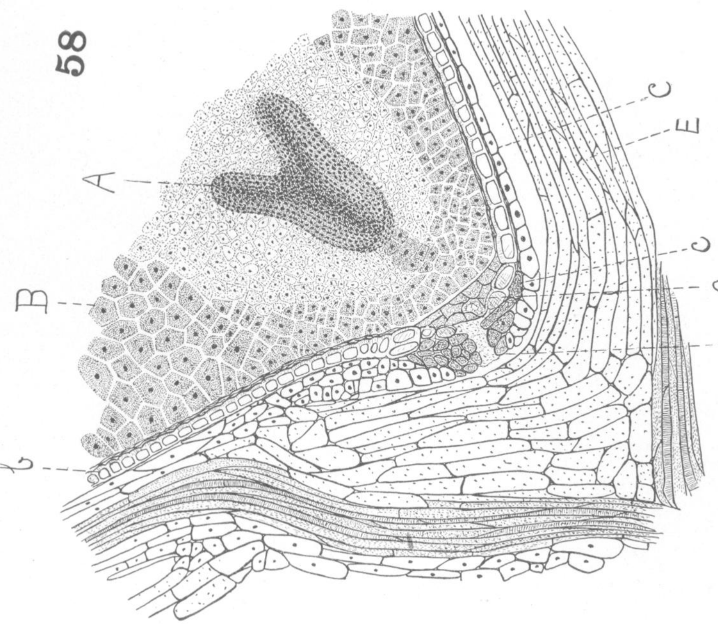

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